（別紙様式５）

# 変革を駆動する先端物理・数学プログラム（FoPM）
# 国外連携機関長期研修　報告書

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## Backgrounds

I visited and conducted training at both the Massachusetts Institute of Technology (MIT) and the University of California, Riverside (UCR) to advance my expertise in the development and application of diamond nitrogen-vacancy (NV) center sensors. My research focuses on two interdependent pillars: designing innovative measurement techniques that harness the quantum properties of NV centers and exploring their extensive applications in material property measurements. Achieving breakthroughs in this field requires progress in both the theoretical design of NV center-based measurement methods and their practical implementation. MIT, with its renowned strengths in quantum information science and sensor technology, and UCR, recognized for pioneering work in superconductors and device fabrication, offer complementary environments that together provide a comprehensive framework for my training.

## Training at MIT

At MIT, I had the distinct opportunity to work with Prof. P. Cappellaro, a leader whose seminal contributions—including the landmark paper [Taylor et al. Nat. Phys. 4, 810–816 (2008)]—laid the foundation for utilizing diamond NV centers as sensors. Prof. Cappellaro's blend of deep theoretical insights and practical innovation, as evidenced by her numerous patents (including those on NV-based gyroscopic sensors), served as a powerful source of inspiration. During my stay, I participated in a project that employed entangled nuclear spin states to enhance the sensitivity of vector magnetic field measurements. This endeavor required a careful integration of theoretical modeling with experimental validation—a hallmark of MIT's approach to research.

Fig.1 The frozen Charles River, just behind the MIT campus.

The intellectual climate at MIT is both dynamic and collaborative. In shared workspaces, students and postdoctoral researchers engaged in spontaneous problem-solving sessions and in-depth discussions on experimental setups and theoretical challenges. Weekly seminars, organized by the extensive quantum information community that spans MIT and nearby Harvard University, provided a forum for dialogue with leading figures such as Prof. W. D. Oliver, M. D. Lukin, and N. Y. Yao. These formal sessions were complemented by informal exchanges through mailing lists, where even the finer details of experimental techniques were openly discussed. Furthermore, my involvement with the Research Laboratory of Electronics (RLE) broadened my exposure to interdisciplinary research. Engaging with groups like Prof. P. Jarillo-Herrero's team, known for their work on superconductivity in magic-angle twisted bilayer graphene, enriched my understanding of how diverse scientific approaches can converge to solve complex problems.

## Training at UCR

At UCR, I worked under the guidance of Prof. S. Cybart, a pioneer in device fabrication who is celebrated for his breakthrough in realizing the first successful Josephson junctions in copper oxide high-temperature superconductors using a helium ion microscope. This advanced instrument, capable of fabricating gaps as narrow as 2 nm, provided me with invaluable hands-on experience. I learned sophisticated techniques for fabricating superconducting devices and measuring the electromechanical properties of Josephson junctions, thereby gaining practical insights into the challenges of device fabrication.


Fig.2 Box Springs Mountain, a desert mountain located just behind the UCR campus.

The research environment at UCR is markedly different from that at MIT. While MIT is characterized by large-scale intellectual exchanges, UCR offers a more intimate setting where tight-knit research teams foster continuous, focused discussions. Here, the emphasis on experimental precision and technical excellence allowed me to delve deeply into the intricacies of device fabrication. Daily interactions in the lab were dedicated to troubleshooting, refining, and optimizing experimental methods. This immersive, hands-on approach not only enhanced my technical proficiency but also underscored the critical role of precision in translating theoretical concepts into practical devices.

## Reflections and Collaborative Impact

These experiences were exceptionally rare in my research career, which had primarily centered on domestic collaborations. Extended stays in both the subarctic Northeast and the arid West Coast exposed me to diverse environments and cultural nuances, offering fresh perspectives and daily opportunities for discovery. While the specific themes of my visits were not directly aligned with my current research, the collaborative projects initiated during these periods have since evolved into a major focus of my work.

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